Estuarine Management and Technologies Journal

Estuarine Management and Technologies 3: 87–112 (2026)
DOI: 10.3897/emt.3.186569

Review Article

Macroalgae in coastal lagoons: a systematic review from Brazil

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Abstract

Coastal lagoons (CLs) are important ecosystems that perform relevant ecological functions and provide goods and services essential to human well-being. Lagoons occupy 13% of the planet's coastal area, but due to intense urbanization of their surroundings, they are among the most threatened ecosystems globally. Macroalgae play an important role in ecosystem functioning and are widely used as effective bioindicators for environmental monitoring. Despite this we know little about the distribution of CLs in Brazil and less about the macroalgae they may contain. We mapped lagoons using Google Earth and assessed macroalgae presence through a systematic literature review (September 2021–March 2022) of five databases and two languages using the keywords: (alga OR seaweed) AND (lagoon) AND (Brasil* OR Brazil*). We identified 300 unevenly distributed lagoons along the Brazilian coast with little floristic similarity. The Rio Grande ecoregion had the highest concentration of CLs (n = 124), followed by the northeast and southeast; three of 17 coastal states had none. We catalogued 213 macroalgae taxa in 48 studies across only 11 lagoons, with little similarity among lagoons. Most research focused on two, the Patos and Araruama Lagoons. The lack of studies of macroalgae represents a significant knowledge gap for Brazil's coastal zone — we don't know if these lagoons are highly unique (high beta diversity) or simply understudied. We encourage more targeted research on lagoons such as the PELD long-term monitoring programs so that the flora may be used for monitoring ecological status.

Key words: Aquatic ecology, bioindicators, coastal ecosystems, lagoon studies, marine conservation, seaweed

OPEN ACCESS

Academic editor: Tri Soeprobowati
Received: 26 January 2026
Accepted: 7 March 2026
Published: 19 March 2026

Citation: Amaral HBF, Copertino M, Creed JC (2026) Macroalgae in coastal lagoons: a systematic review from Brazil. Estuarine Management and Technologies 3: 87–112. https://doi.org/10.3897/emt.3.186569

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Introduction

Coastal lagoons (CLs) are among the most productive ecosystems in the world and are of extreme ecological, social, and economic importance (Knoppers et al. 2009; Pérez-Ruzafa et al. 2024). Macroalgae contribute significantly to the productivity of many CLs. These systems provide numerous ecosystem goods and services such as transport, food, water, raw materials, habitat, nursery, carbon sequestration, climate regulation, tourism and others that go beyond the lagoon itself, benefiting society in a broader spatial and historical context (Newton et al. 2014; Rodrigues-Filho et al. 2023). Occupying 13% of coastal areas worldwide,

CLs coincide with many densely populated areas (Kjerfve 1994; Newton et al. 2014; 2018). Nearly 50% of coastal wetland areas have been lost or degraded over the last 100 years as result of the combined effects of local human pressures and climate change impacts (Oppenheimer et al. 2019). Despite their recognized importance for biodiversity conservation and humanity (Barbosa et al. 2004), CLs are seriously threatened (Esteves et al. 2008; Dias 2024; Breitburg et al. 2018; Brauko et al. 2020) and the macroalgae within these systems are also similarly threatened. For example, warming trends which are consistent with global and regional climate forecasts in temperature have been found in all Marine Ecoregions of Brazil during the last decades, (Bernardino et al. 2015) and according to projections from the Coupled Model Intercomparison Project phase 5, the global mean sea level is expected to rise by 0.28 to 0.98 m above the 20-year mean of 1986–2005 by the year 2100 (Church et al. 2013).

By definition, CLs are saline or brackish shallow water bodies, typically oriented parallel to the coastline, separated from the ocean by sand barriers, shoals, reefs or chain of islands (coastal barriers), with restricted or ephemeral access to the sea through one or more tidal channels (Kjerfve 1994; Knoppers et al. 2009). They may or may not be subject to tidal mixing, therefore can range from freshwater to hypersaline (Kjerfve 1994). CLs are ecotones that connect adjacent terrestrial and aquatic ecosystems, exhibiting high biodiversity due to the movement of organisms during various life stages (De Witt 2011; Esteves et al. 2008). These areas serve as spawning and nursery grounds for many species, including those of commercial interest. Their multiple transition boundaries – with the sea, coastline, terrestrial environment, atmosphere, sediment, and freshwater sources – create an energy field shaped by diverse physicochemical gradients, which explains their high productivity. The shallow depth of most CLs allows the photic zone to reach the bottom, and frequent coastal winds lead to sediment resuspension, in addition to the strong influence of nutrients supplied by adjacent terrestrial environments (Pérez-Ruzafa et al. 2024).

CLs are characterized by their high productivity, with annual primary production ranging from 50 to > 500 $g.cm^{-2}.year^{-1}$, making them comparable in magnitude to upwelling areas (Pérez-Ruzafa et al. 2024). These authors explain that this high productivity is due to both trophic factors and physical characteristics. These ecosystems are shallow, allowing the photic zone to extend to the sediment, and are influenced by wind patterns and strong benthic-pelagic coupling. Moreover, CLs act as nutrient sinks, receiving inputs from surrounding terrestrial environments and watersheds, which are essential for their productivity (Kennish 2015). Macroalgae, phytoplankton and seagrasses are responsible for primary productivity in estuarine and CL environments (Esteves 1998), as well as the emergent vascular plants (mangroves, salt marshes), which are frequently found around lagoons (depending on the latitude). In these systems, the production of benthic algae and seagrasses can surpass the production of phytoplankton (Kennish 2015). These organisms play key roles in carbon sequestration, nutrient cycles, and trophic links, enhancing secondary production locally and in adjacent waters (Marinho-Soriano and Carneiro 2021; Creed et al. 2023). Changes in primary producers' abundance and composition can alter the trophic structure and functionality of CLs (Schramm 1999; Connell et al. 2008; Scherner et al. 2013). Monitoring those changes has great

potential for revealing the cumulative effects of human pressure on aquatic biota (Borowitzka 1972; Ortega 2000; Orfanidis et al. 2011).

Macroalgae play essential ecological roles and are responsible for providing numerous ecosystem services, such as carbon sequestration, nutrient cycling, and the provision of shelter and nourishment for various marine species (FAO 2018; Hasselström et al. 2018; Marinho-Soriano and Carneiro 2021). However, the efficiency in delivering these services can be severely compromised by prolonged natural and anthropogenic disturbances. Exposure to such stressors triggers biochemical and physiological alterations within algal populations and communities, reducing their functional capacity and signaling environmental degradation. Due to this sensitivity, macroalgae are widely recognized as excellent bioindicators, accurately reflecting the conservation status of the marine environment (Ortega 2000; Orfanidis et al. 2011; Ferreira 2020). In CLs, macroalgae can grow entangled or as epiphytes on vascular plants, or direct on the unconsolidated or hard substrate (Creed and Casares 2005). Composed of fine filaments and simple tissues, macroalgae respond very quickly to changes in water parameters, such as depth, turbidity, light and nutrients and are used as bioindicators of pollution and contamination (Orfanidis et al. 2011; Pérez-Ruzafa et al. 2019). In general, macroalgae have lower light requirements than seagrasses, growing deeper or in more turbid waters due to their accessory pigments, which allow them to absorb a broader spectrum of light (Raven et al. 2014). Opportunist macroalgae can grow fast under eutrophic conditions, in detriment to seagrasses or larger macroalgae as they have higher nutrient requirements (Copertino et al. 2016; Lanari et al. 2017; Esteves et al. 2008). Therefore, macroalgal species composition and morphological traits can reflect the water quality and health status of CLs.

In general, in the literature, CLs overlap with estuaries. In Brazil, forty-one large estuaries (coastal plains, fjords, tectonic, barbuilt, lagoons) have previously been reported, including two CLs, the Araruama and Patos Lagoons and the Mundaú-Manguaba estuarine lagoon complex (Lessa et al. 2018). According to Bernardino et al. (2015) Brazil has more than 100 estuaries, which include inside them various ecosystems such as salt marshes, mangroves and CLs. It has been suggested that CLs occupy 12% of coastal regions in South America (Cromwell 1971; Barnes 1980). Despite their relevance and growing threats, no attempt has been previously made to map and assess CLs along the 8.500 km of the Brazilian coast. There is a lack of monitoring of the environmental quality for most of these ecosystems that could exploit the biota, such macroalgae, as indicator species. Estuarine and CL macroalgal communities have been neglected from most phycological studies in Brazil and elsewhere, which are concentrated in coral reefs and coastal and marine rocky intertidal and subtidal environments.

Understanding the composition of existing macroalgal flora and the temporal and spatial dynamics of these assemblages can be used to assess the conservation status and consequently better manage to preserve CLs and their ecosystem services. To fill this gap, this study aims first to identify the CLs along the entire Brazilian coast and secondly to conduct a systematic review about the macroalgal occurrence and knowledge in these environments in order to assess similarities and differences in the flora.

Materials and methods

Geographical distribution

CLs in Brazil were identified by the inspection of the entire Brazilian coastline using Google Earth images at the 200–1000 m scale (accessed in March 2022). Each lagoon was georeferenced with a single point (central location) generating a kmz file. The inclusion criteria were coastal water bodies, usually oriented parallel to the coastline and separated from the ocean by barriers with restricted or ephemeral access to the sea (Kjerfve 1994). Lagoons with their margin at the sandy coastal strip, showing a clear relationship with the marine environment, were included. Additionally, a cut off distance of a maximum of 5.5 km from the maritime coastline was used to exclude non-coastal water bodies. CLs with or without a connection channel to the sea were considered, as these channels can alternate between open and closed through anthropic interference or natural processes. Given the complexity of this coastal environment for a more precise categorization, we considered the marine ecoregions (Spalding et al. 2007). The spatial distribution of lagoons was scored regionally according to the marine realms (the Tropical Atlantic and the Temperate South America), provinces (Northern Brazilian Shelf, Tropical Southwestern Atlantic, and Warm Temperate Southwestern Atlantic) and eight ecoregions (according to Spalding et al. 2007), as well coastal states.

Systematic knowledge review

Searches were conducted of the SciELO (Scientific Electronic Library Online), Web of Science (Clarivate Analytics) and Scopus (Elsevier) databases, as well as Google Scholar and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) Periódicos Portal thesis and dissertations database, hereafter referred to as the CAPES Journals database. Searches were carried out from January 9, 2021 to March 14, 2022, using the keywords: (*alga* OR seaweed) AND (lagoon*) AND (Brazil* OR Brasil*). Searches were conducted without language or time restrictions. Only peer-reviewed scientific articles were considered, except in the CAPES Journals database, where theses and dissertations were included.

The ‘Topic’ field was used in Web of Science, and the ‘TITLE-ABS-KEY’ field was used in Scopus. In databases where the search results exceeded 3000 documents, filters were applied. In Scopus, CAPES Journals, and Google Scholar databases, filters were applied for English and Portuguese languages. In Scopus, filters for ‘article’, ‘review’, and ‘conference paper’ were used, and in CAPES Journals, filters for ‘articles’ and ‘peer-reviewed journals’ were applied. Additionally, in CAPES Journals and Google Scholar databases, a new filter was applied to exclude papers containing the words ‘phytoplankton’, ‘zooplankton’, ‘cyanobacteria’, and ‘fish’. In the Scopus, WOS, and SciELO databases, results were downloaded in an Excel spreadsheet format for analysis, while in Google Scholar and CAPES Journals, analyses were conducted on the website itself.

Selection was conducted by one researcher reading the abstract and when necessary (unclear abstract information) the full text. The criteria applied for bibliography selection included papers published on macroalgae in Brazilian CLs, which could contain information on richness, biomass, experimental approaches, or pollution in macroalgae, as long as the title or abstract referred to the theme. Returns related to phytoplankton, Charophytes, lakes, reservoirs, or

outside the country were excluded. Studies conducted in estuaries that do not connect to lagoons were not included here. To expand the scope of this review, after filtering the retained articles had their bibliographies analyzed, and additional documents that did not appear in the databases search were included through snowballing (additional references contained in the retained sources). In this second stage, non-indexed documents (grey literature) were considered, in addition to the inclusion criteria above. We also consulted the national online curricula database (Plataforma Lattes of the Conselho Nacional de Desenvolvimento Científico e Tecnológico) of all the coauthors of these shortlisted documents to check for any further relevant published documents which might not have appeared in the previous searches. This was to avoid loss of information since the keywords used focused on macroalgae and CLs, but some studies may have referred to submerged aquatic vegetation, producers, specific macroalgae species, or studies with some other primary focus.

We also conducted searches in the Catalogue of Theses and Dissertations of CAPES using the names of each lagoon identified in Stage 1 of the systematic review (see flowchart), combined with the keyword “macroalgae” and we inspected the first 200 studies of each search. Finally, the bibliographic database was then supplemented with references from the Laboratório de Ecologia Marinha Bêntica database at the Universidade do Estado do Rio de Janeiro. These searches ensured the most comprehensive possible level of inclusion of relevant studies and documents, as well as other sources that were records of the authors’ prior knowledge. Thus, this review considered peer-reviewed scientific articles, conference proceedings, technical reports, monographs, dissertations, and theses, including both indexed publications and grey literature, provided they met the established inclusion criteria (as shown in Fig. 1).

All documents were compiled in an Excel spreadsheet, and a second filtering was performed where duplicate documents were excluded. The database was standardized with one row for each source as a unique reference number, the source database(s), relevant bibliographic information (Author(s), Date, Title, year, file types, etc.), and a copy of the publication. The data were compiled (localization, lagoon, macroalgal species occurrence, subject/topic of source, availability of biomass information), and a database on macroalgae in Brazilian CLs was thus constructed. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al. 2021) was used to formalize and analyze the exclusion of references, as well as to generate a flowchart reporting the selection criteria and process for obtaining the references used. After filtering and screening, a flowchart (Fig. 1) was prepared as suggested by Moher et al. (2015) updated in 2020 by Page et al. (2021).

In light of the debate on the use of non-indexed works in reviews and bibliometric studies, all references were classified into two categories by formality: peer review literature (scientific journals only) and grey literature (remaining categories) (Bellefontaine and Lee 2014). Each reference found was classified by the type of document: scientific article, conference proceedings, monograph, dissertations, and theses. In addition to being classified according to the database(s) where they were found, we also categorized them according to the theme/subject addressed in the study: full floristic survey, partial floristic survey (citation of occurrences), biomass records, experimental assays, use as bioindicators, and the use of any indices.

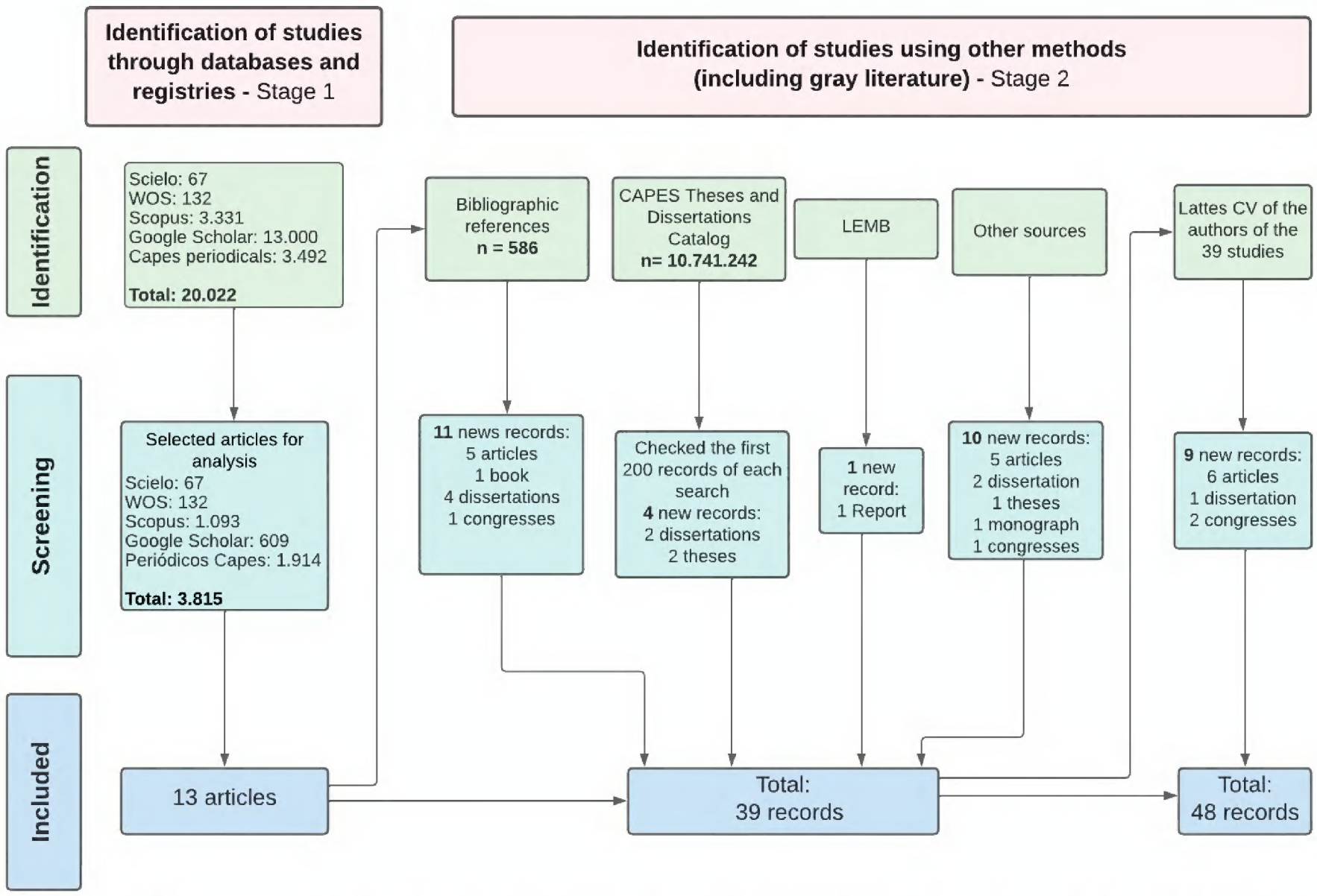

Figure 1. PRISMA flowchart demonstrating the search steps for identifying records of studies of macroalgae in Brazilian lagoons.

Analysis of titles

An analysis of titles was conducted using the words contained in the titles of all retained documents. The words were extracted from the database to produce a single document, which was manually edited by removing unspecific terms, combining very similar words (plurals, derivatives), and cutting off on three or fewer repetitions. After editing, a word cloud was generated to visualize major topics using an online word cloud generator (https://www.wordclouds.com/).

Macroalgal occurrence

A checklist of all macroalgal taxons occurring in the studied CLs was compiled from species lists and citations throughout the texts (at least to the mention of genus level) from the papers found in this systematic review. The nomenclature was updated according to Guiry and Guiry (2013). For multivariate comparison of the macroalgal assemblages of different lagoons we used the Primer 5 package (Primer-E Ltd.) to generate Bray-Curtis similarity coefficients from the presence-absence data which were compared with a Cluster Analysis and Multi-Dimensional Scaling (MDS).

Results

A total of 300 CLs were identified (Fig. 2 and Suppl. material 1: S1). They were found in all the Brazilian marine ecoregions (Fig. 2), with the Rio Grande ecoregion having the highest proportion of CLs (41,3%), followed by the Northeast (25,7%) and then the Southeast (17%) ecoregions (Table 1, Fig. 3a). Brazil has 27

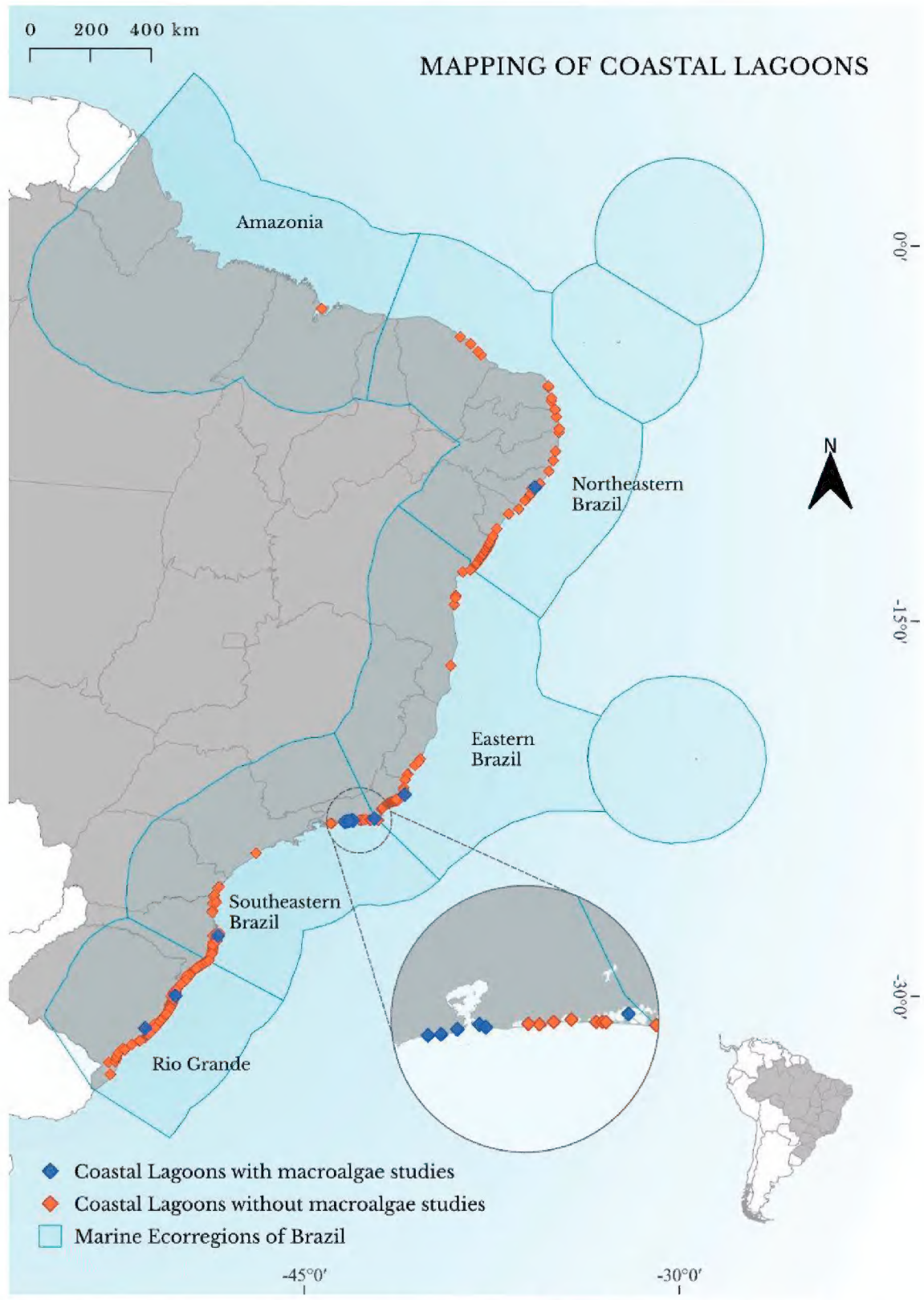

Figure 2. The distribution of Brazilian CLs identified along the Brazilian coast, per marine ecoregion (Spalding et al. 2007) and federal state, according to the present review. Blue diamonds indicate lagoons with records of studies of macroalgae and red diamonds indicate where no such studies were found. A list of all Brazilian CLs mapped in this study can be accessed at Suppl. material 1: table S1.

states, 17 of which are coastal; among these, only three states (Amapá, Pará and Piauí) did not have typical CLs. The highest proportions of the number of lagoons were found in the states of Rio Grande do Sul (29%), Santa Catarina (22,6%), Rio de Janeiro (17%) and Bahia (16% each) (Fig. 3b, Suppl. material 1: S1).

A total of 20.002 initial documents were found in the research databases, with 67 in Scielo, 132 in Web of Science, 3.331 in Scopus, 13.000 in Google Scholar, and 3.492 in Periódicos Capes. After screening, only 13 documents were retained following the inclusion/exclusion criteria. The base that yielded the highest number of results was Web of Science, with seven (33%), followed by Scopus with six articles (29%) and more than half were exclusive to one or another database (Fig. 4). The study that appeared most frequently across different databases was about the influence of piers on the functional groups of benthic primary producers and consumers in the channel of Conceição Lagoon- SC (Pagliosa et al. 2012), listed in four out of the five bases.

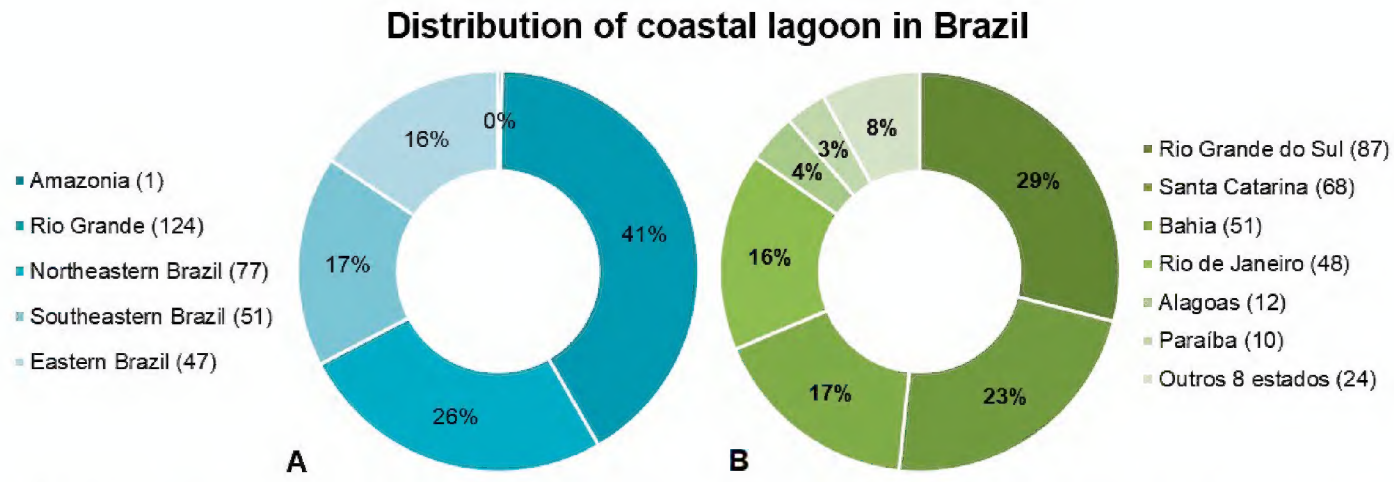

Figure 3. The proportion of Brazilian coastal lagoons by (**A**) marine ecoregion and by (**B**) coastal state (n in brackets). Others include states with fewer than 5 coastal lagoons.

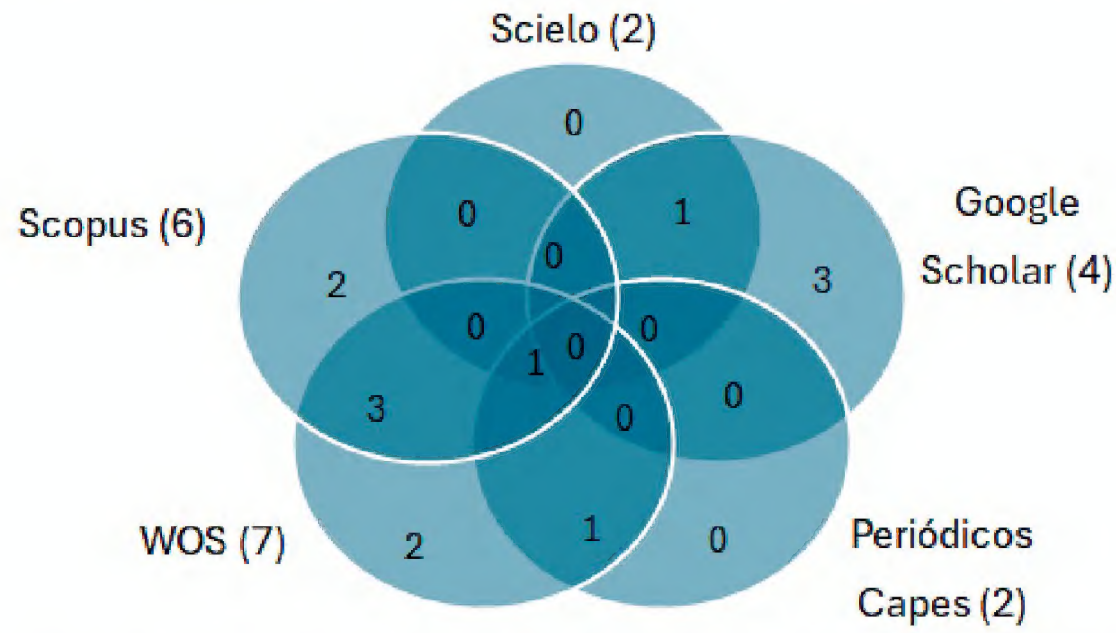

Figure 4. Venn diagram of the sources of the 13 documents retrieved from the Web of Science, Scopus, Scielo, Google Scholar, and Periódicos Capes database, mentioning aspects of macroalgae in lagoons along the Brazilian coast.

The 13 articles generated a total of 586 secondary records (bibliographic citations). After analysis and exclusion of duplicates, 14 additional references were added, resulting in the addition of 11 documents that were included in this review (Fig. 1). From searches in the Capes Theses and Dissertations Database, four documents were added, two theses, one about the Araruama Lagoon (RJ) and another about the Patos Lagoon (RS), and two dissertations, one about Araruama, Tijuca, and Rodrigo de Freitas Lagoons (RJ) and another about Conceição Lagoon (SC). A search of the Laboratório de Ecologia Marinha Bêntica database generated one additional reference and from other sources, ten references were included, totaling 39 studies. From these 39 references, 62 authors were listed. A search for the publications of the 62 co-authors in the Curriculum Lattes database revealed nine additional records, totaling 48 studies of macroalgae in CLs in Brazil (Fig. 1, Suppl. material 1: S2). Although it was not possible to obtain one study (Tramandaí Lagoon), it was included due to other works that cite the species list of this lagoon.

A total of 48 studies were found containing information about macroalgae in 11 different Brazilian CLs (Tables 1, 2). These findings cover macroalgal research carried out in four of the five marine ecoregions along the Brazilian continental coastline (Spalding et al. 2007) (Table 1). Within the Amazon ecoregion, only one CL was identified—Jansen Lagoon—the northernmost lagoon recorded in the country. All CLs with documented macroflora are connected to the sea. However, the study effort varied geographically among lagoons and regions. For example,

Table 1. Distribution of coastal lagoons along the Brazilian coast by Marine Ecoregions of the World and details of those studied regarding their macrophyte flora. *The references do not include studies from Tramandaí Lagoon, but they mention the species list of that lagoon.

Realm	Province	Ecoregion	Total number of lagoons	Lagoons with macroalgae sampling / State	Number of works	References
Tropical Atlantic	North Brazil Shelf	Amazonia	1	–	–	–
	Tropical Southwestern Atlantic	Northeastern Brazil	77	Lagoa de Mundaú/AL	1	Wallner et al. 1986.
		Eastern Brazil	47	Lagoa do Açú/RJ	2	Yoneshigue-Valentin et al. 2002; Esteves et al. 2005.
Temperate South America	Warm Temperate Southwestern Atlantic	Southeastern Brazil	51	Lagoa de Araruama/RJ	8	Yoneshigue and Coutinho 1976; Reis 1990a, 1990b; Reis and Yoneshigue-Valentin 1996; Lavrado 1998; Lourenço et al. 2005; Amaral 2014; Amaral et al. 2018.
				Lagoa de Itaipú/RJ	4	Oliveira 1948; Sá and Guimarães 1984; Pedrini et al. 1998; De Paula and Pedrini 1998.
				Lagoa de Piratininga/RJ	3	Oliveira 1948; Cunha 1996; Pedrini et al. 2002.
				Lagoa Rodrigo de Freitas/RJ	6	Loureiro 2007; Loureiro and Reis 2008; Araujo 2014; Amaral 2014; Araujo et al. 2017; Amaral et al. 2018.
				Lagoa da Tijuca/RJ	4	Wallner et al. 1986; Figueiredo et al. 1989; Amaral 2014; Amaral et al. 2018.
				Lagoa de Marapendi/RJ	2	Pedrini and Silveira 1985; Pedrini et al. 1997.
				Lagoa da Conceição/SC	3	Böker-Tôrres 2005; Böker-Tôrres et al. 2009; Pagliosa et al. 2012.
		Rio Grande	125	Lagoa de Tramandaí/RS	4	Prado 1989; Prado 1991; Biancamano 1995; Alff 2017 (*Pedrini et al. 2002; Böker-Tôrres 2005; Böker-Tôrres et al. 2009).
				Lagoa dos Patos/RS	17	Seeliger and Cordazzo 1982; Coutinho 1982; Coutinho and Seeliger 1984; Coutinho and Seeliger 1986; Copertino and Seeliger 2010; Gianasi et al. 2011; Claudino 2012; Rosa and Garcia 2013; Lanari 2016; Garcia et al. 2016; Lanari and Copertino 2016; Lanari et al. 2017; Lanari et al. 2018a, 2018b; Lanari et al. 2021a, 2021b; Lemos et al. 2022.

17 documents addressed macroalgae in the Patos Lagoon, while 22 documents addressed macroalgae in seven different lagoons in Rio de Janeiro (Table 1). Seventeen studies were conducted in only one lagoon, two in three lagoons simultaneously (Araruama, Rodrigo de Freitas, and Tijuca Lagoons), and one study covered a lagoon in Rio de Janeiro (Tijuca Lagoon) and another in Alagoas (Mundaú Lagoon). Of the 17 coastal states in Brazil, only four have CLs with macroalgae studies: Alagoas, Rio de Janeiro, Santa Catarina and Rio Grande do Sul.

The median surface area of the studied lagoons is 13 km2, with an average depth of 2,41 m and an average salinity of 17,81 (Table 2). There was a strong and positive relationship between lagoon size (area, Table 2) and the number of macroalgae studies conducted there (Table 1) (Pearson's $r = 0.92$, $p < 0.01$, $df = 9$).

Twenty-seven out of 48 studies provided a list of macroalgae species, while 21 cited some occurrences or mentioned only one species. Eleven studies were experimental in nature (23%), 23 studies (58%) used macroalgae biomass in their methodology, five used isotopes and four focused on bioindicators, but only one study used an index with macroalgae. Nevertheless, 22 studies addressed some relationship between macroalgae and eutrophication/pollution (Fig. 5).

Table 2. Geographic location, surface areas, depths, salinities, and tidal ranges of the Brazilian lagoons studied from the perspective of their marine macrophyte flora. All lagoons mentioned are of the choked type according to the classification proposed by Kjerfve (1994). The data were derived from the references listed in Table 1.

Lagoon	State	Surface Area (km²)	Average depth (m)	Average salinity	Latitude, Longitude	Tide range
Lagoa de Mundaú	AL	24.0	1.5	27.0	9°38'31"S, 35°45'56"W	Mesotides
Lagoa do Açu	RJ	10.0	2.5	35.7	21°55'03"S, 40°58'58"W	Microtide
Lagoa de Araruama	RJ	220.0	2.9	52.0	22°52'57"S, 42°11'45"W	
Lagoa de Itaipú	RJ	1.2	1.0	25.5	22°57'42"S, 43°02'32"W	
Lagoa de Piratininga	RJ	2.9	0.6	23.4	22°56'42"S, 43°04'48"W	
Lagoa Rodrigo de Freitas	RJ	2.2	2.8	17.0	22°58'26"S, 43°12'40"W	
Lagoa da Tijuca	RJ	4.8	2.1	17.2	23°00'14"S, 43°18'28"W	
Lagoa de Marapendi	RJ	3.5	1.8	20.5	23°00'35"S, 43°23'06"W	
Lagoa da Conceição	SC	20.7	1.7	15.2	27°34'09"S, 48°27'21"W	
Lagoa de Tramandaí	RS	13.0	1.1	21.0	29°57'54"S, 50°09'13"W	
Lagoa dos Patos	RS	10227.0	5.0	16.0	31°52'23"S, 52°06'48"W	

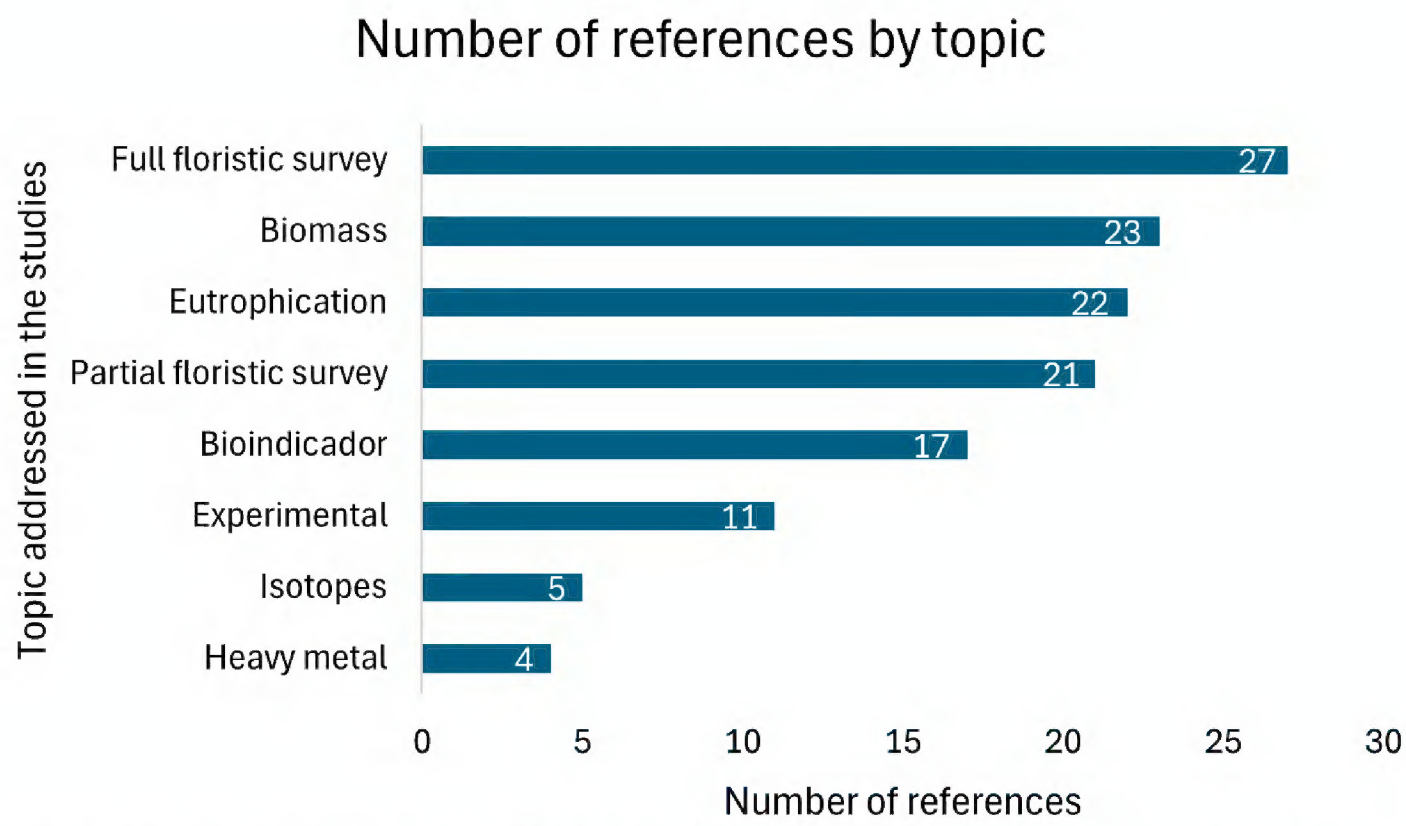

Figure 5. Topics addressed in studies of macroalgae in Brazilian coastal lagoons. Studies are not exclusive.

The northernmost CL in Brazil with records of marine macroalgae is the Mundaú Lagoon, with one study of *Enteromorpha* sp. and its relationship with heavy metals (Wallner et al. 1986). The southernmost lagoon with records of macroalgae is the much studied Patos Lagoon, with a total of 17 records distributed among taxonomic and ecological studies (n = 5), bioindicators and heavy metals (n = 2), drifting macroalgae (n = 4), isotopes (n = 5), and the use of satellite imagery for analyzing macroalgae blooms (n = 1). It is noteworthy that the only studies involving isotopes in marine macroalgae in Brazilian CLs have been conducted in this lagoon.

The frequency and number of published studies increased over time (Fig. 6). The earliest study is a review of the Itapú and Piratininga Lagoons (Oliveira 1948), a hydrological study which mentions the occurrence of some macroalgae. It is the first study to provide a list of macroalgae species in CLs in Brazil and is followed by the Araruama Lagoon (Yoneshigue and Coutinho 1976). The pioneering study on macroalgae as bioindicators of heavy metals was conducted in the Patos

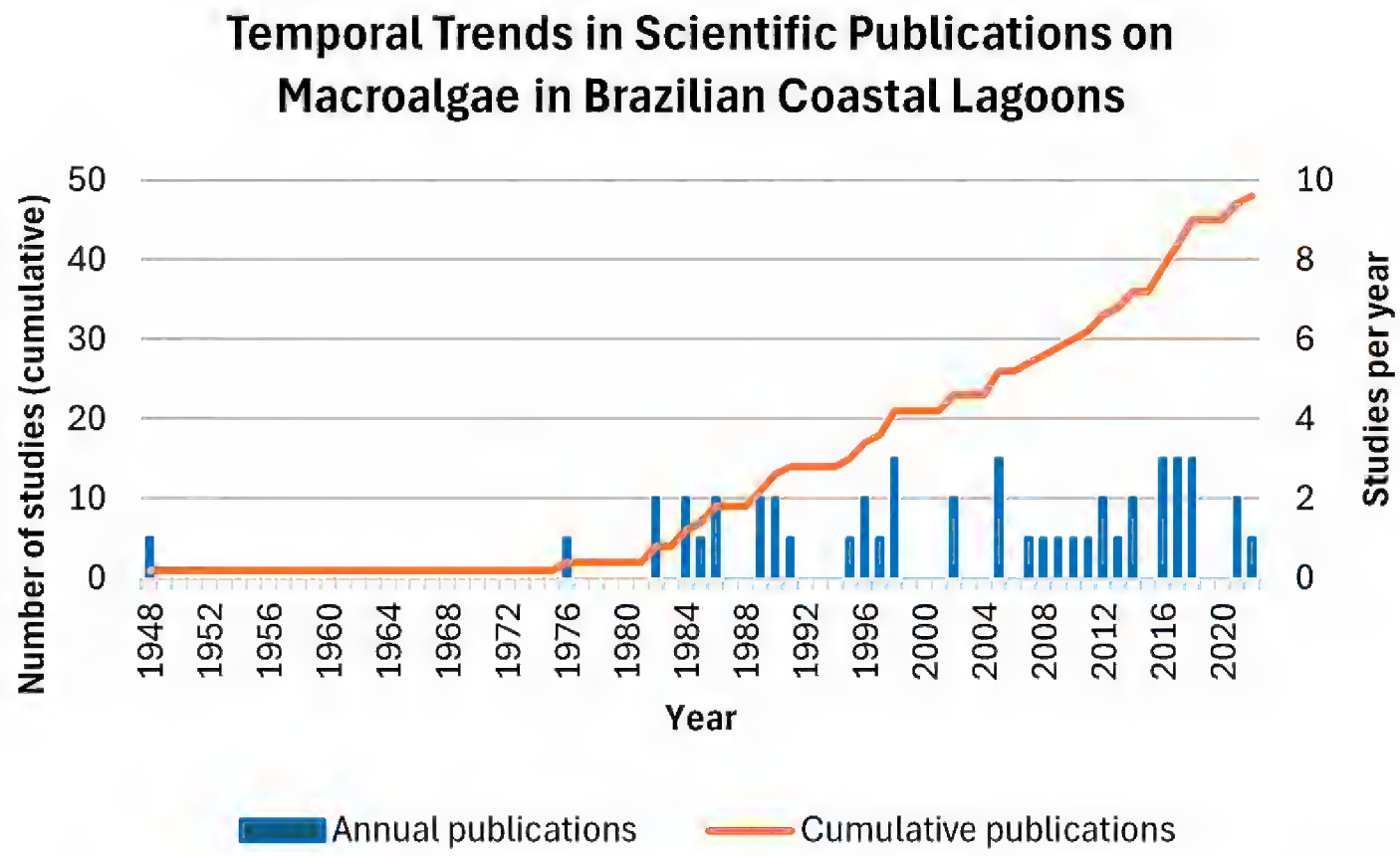

Figure 6. Number and frequency of studies of marcoalgae in coastal lagoons along the Brazilian coast.

Lagoon (RS), followed by the Mundaú Lagoon (AL), Tijuca Lagoon (RJ), and Rio Ceará (CE), all in the 1980s. Only one study, conducted in the Araruama Lagoon, investigated the structure of phosphorus and nitrogen in algal tissues, also serving as an excellent reference for biological indicators (Lourenço et al. 2005).

Although this review focused on studies conducted in CLs, all research was carried out in lagoons (i.e. with communication channels to the sea). Furthermore, 26 out of 48 studies were conducted within the communication channel between the lagoon and the sea, but only ten of these clearly indicated in the title that they are about the estuary or the lagoon channel. We included these studies as part of the lagoon flora.

Two hundred and three macroalgal taxa were listed from the 48 studies conducted in the 11 Brazilian lagoons, with 56% Rhodophyta, 32,4% Chlorophyta, and 11,7% Ochrophyta (Suppl. material 1: S3). Taxonomic nomenclature was updated according to AlgaeBase, with synonyms and non-accepted names standardized to currently accepted taxa. Records of morphologically plastic or polymorphic taxa (e.g., *Ulva* spp.) were revised according to current taxonomy. Nevertheless, as original identifications in older studies could not be re-examined, possible misidentifications - particularly in taxonomically complex groups - may have contributed to an inflated richness estimates. The richest lagoon was the Araruama Lagoon (RJ) with 119 taxa, followed by Itaipú Lagoon (RJ) with 72 taxa, Patos Lagoon with 60 and Conceição Lagoon with 56 taxa, respectively (Fig. 7). The most common taxa were *Ulva* spp., *Chaetomorpha* spp., *Cladophora* spp., *Bryocladia subtilissima*, *Gymnogongrus griffithsiae* e *Feldmannia* spp.

The macroalgal assemblages were very dissimilar between lagoons, with none of the assemblages grouping at the 50% similarity cutoff (Fig. 8). Even at the 20% similarity cutoff four groups formed, with Mundaú and Açú lagoons forming single-lagoon groups (Fig. 8, Suppl. material 1: S4). At this level the other lagoons were grouped into two clusters, with more slightly more similar phycological floras: one cluster includes the Araruama, Itaipu, Conceição, and Patos lagoons, while the other groups together the Tramandaí, Rodrigo de Freitas, Tijuca, Piratininga and Marapendi lagoons.

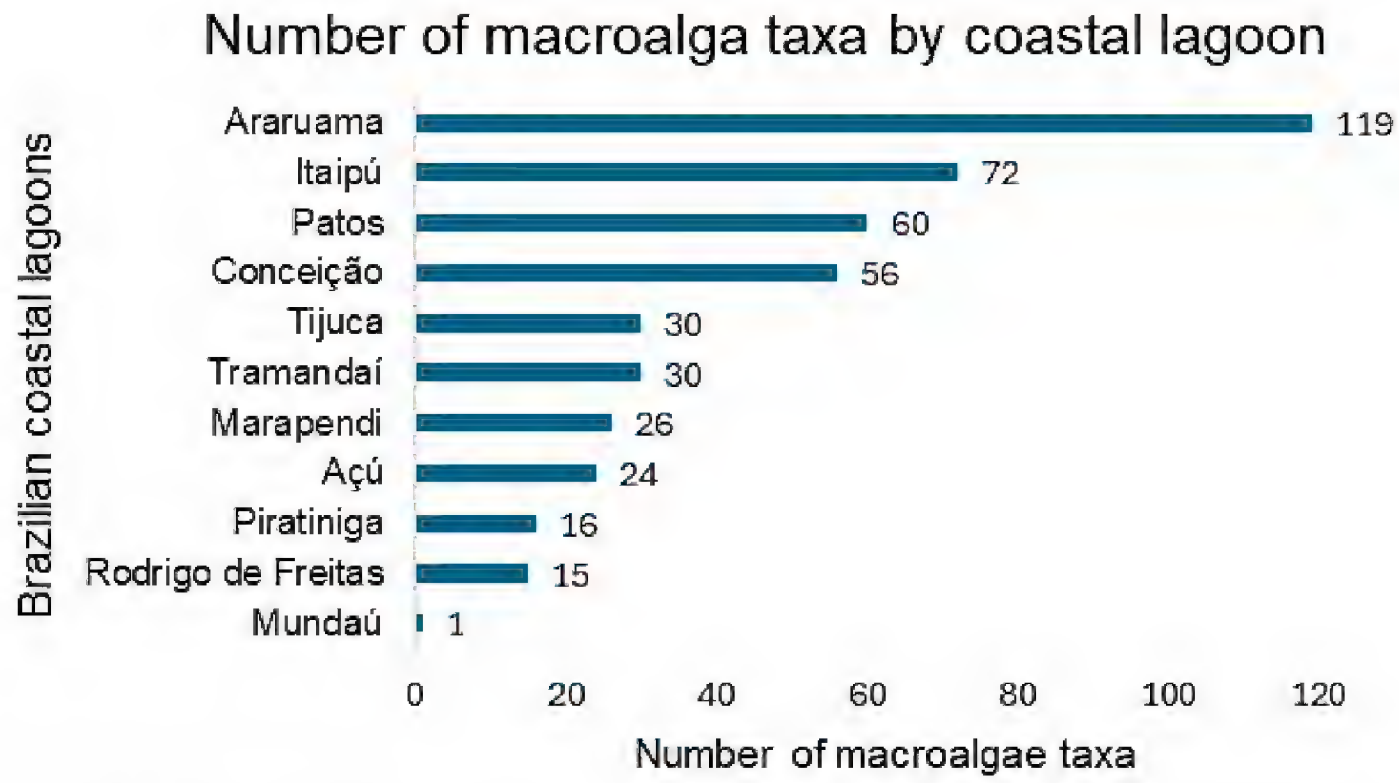

Figure 7. Number of macroalgae species in each analyzed Brazilian lagoon

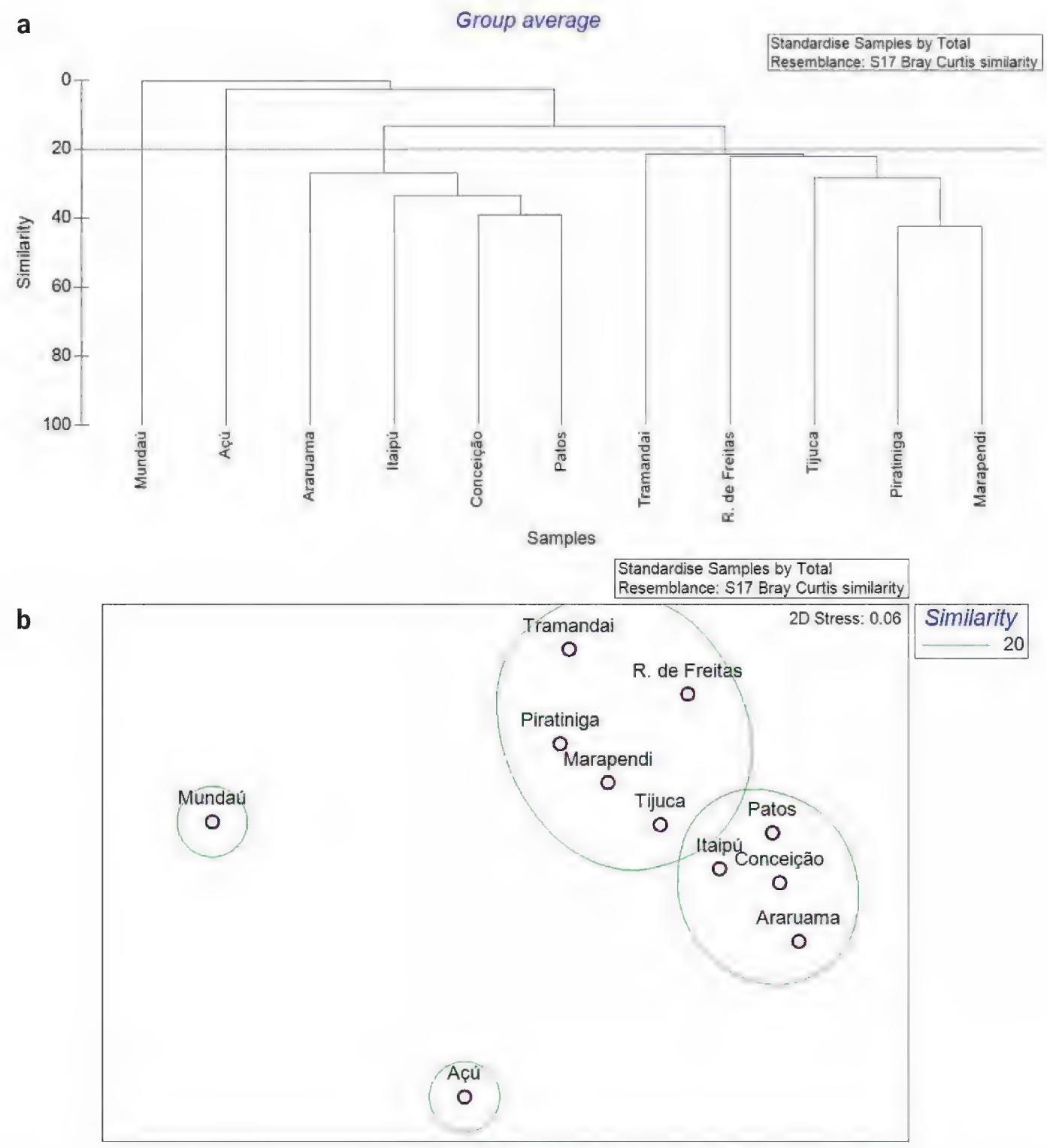

Figure 8. Similarity of macroalgal assemblages between the 11 studied lagoons **a.** Cluster analyses dendrogram; **b.** Multi-Dimensional Scaling (MDS) with grouping established at the 20% similarity cutoff. Bray-Curtis similarity coefficients based on presence-absence data.

A list of 283 words was generated from titles and after editing 70 words were used in the title analysis, which emphasized the focus of documents on geography, environment, location and taxa (Fig. 9). For example, the word cloud (Fig. 9) highlighted the environment ("lagoon", "estuary", "lagoa", "coastal") and the location ("Brazil", "Rio de Janeiro", "Patos", "Araruama"). Other words related to habitat ("benthic", "estuarine") or taxonomy ("macroalgae", "assemblages", "algas", "composition") or processes ("biomass", "distribution", "seasonal", "variations"). The words that stood out the most from the titles were "lagoon" (n = 27), "macroalgae" (n = 20), Brazil" (n = 18), "estuarine" (n = 17) and "Rio de Janeiro" (n = 13).

Figure 9. Word cloud generated from the relative frequency of use of words present in the titles of the 48 documents which studied macroalgae in coastal lagoons in Brazil.

Discussion

This is the first study to identify, list and estimate the number of CLs in Brazil. According to Bernardino et al. (2015), over 100 estuaries are present along the coastline, containing vegetated ecosystems such as salt marshes, mangroves, seagrasses and other submerged aquatic vegetation. In their review, Bernardino et al. (2015) included the most studied estuarine complexes, many occurring at the mouth of river deltas (e.g. Amazon, Parnaíba, São Francisco, Paraíba, Paranaguá deltas) or large CLs (e.g. Patos Lagoon), where most studies have been concentrated. There is an overlap between bodies of water categorized as CLs with those as estuaries: while not all estuaries are lagoons, almost all CLs are or have estuarine regions. Taking into account the 300 CLs identified in our study, we conclude that there are a significantly larger number of estuaries along the Brazilian coast than previously estimated, each one with its unique morphology, structure and dynamics.

Our results also show that with regard to the macroalgae, most of these systems are understudied or not studied at all, with most ecological information

concentrated in large lagoons nearby research institutes and universities. The understudy of smaller coastal lagoons has also been pointed out as a major knowledge gap in the Mediterranean Sea were conservation norms and scientific studies usually focus on large lagoons (> 0.5 km^2) due to their economic importance (Ligorini et al. 2023). However small lagoons are extremely valuable and common in various parts of the world and due to their small size, they may also be more susceptible to growing stresses like human activity and climate change, making them less resilient to disruption.

The distribution of CLs along the Brazilian coast is not homogeneous, with more lagoons found in the Northeast, East, and Rio Grande ecoregions. All five Brazilian coastal marine ecoregions (Spalding et al. 2007) contain CLs. The presence and abundance of CLs in a given region is dependent on geological evolution, together with actual hydrological and oceanographic factors (Bird 1994; Newton et al. 2014). CLs in Brazil were formed during the Holocene, with the fall in mean sea level (Ângulo et al. 2006). Those systems may now be amongst the most sensitive to the increase of mean sea level and changes in the local hydrological patterns, which are affecting each marine ecoregion or coastal compartments in different ways due to global warming.

The Brazilian coast has been divided into five regions according to domains of coastal ecosystems and tidal regimes (Souza et al. 2005). According to these authors, CLs occur in the south and southeast regions, where there is a dominance of, respectively, microtidal and mesotidal regimes. The tidal regime is also a determining factor in the geomorphology of coastal areas, as has been shown by Hayes (1975). The most favorable regime for the formation of CLs is microtidal, which extends from Arroio Chuí (extreme south) to the Baía de Todos os Santos (Cruz et al. 1985), but as we also found CLs under other tidal regimes, mainly in the northeast region, tidal regime is not the sole factor responsible for the distribution of CLs in Brazil as CLs were found in regions with microtidal, mesotidal, and even macrotidal regimes, such as the Jansen lagoon in Maranhão, which is an exception.

Maranhão has the largest tidal range in Brazil and the third largest in the world. It is worth noting that the formation of Jansen Lagoon which is an igarapé (an Amazon watercourse of first or third order, constituted by a long arm of river or channel) was due to the blocking of a stream and catchment and it is artificially maintained by a sluice gate that controls the inflow and outflow of water because, due to the extremely low tide, all the water from the lagoon would drain out if it was not partially dammed. Although we found no studies of macroalgae, fish (Santos et al. 2014; Cantanhêde et al. 2018) and seagrass (a bioassay on the decomposition of *Ruppia maritima*, (Siqueira et al. 2011) have been studied there.

Despite a larger number of CLs occurring in the southern region of the country, a significant number were also found in the northeast ecoregion, which agrees with the observations of Knoppers et al. (2009), who state that despite the higher frequency of lagoons on the Southeast (Rio de Janeiro – RJ) and South (Santa Catarina – SC and Rio Grande do Sul – RS) coasts, lagoons are also found, albeit less frequently, in the Northeast (Ceará – CE, Rio Grande do Norte – RN and Alagoas – AL), citing the lagoons of Itamaracá (Pernambuco – PE) and Mandaú-Manguaba (AL). The Northeast ecoregion has the second highest number of CLs (75), despite having a mesotidal regime. The CLs along

much of the northeastern coast are formed by the closure of river mouths by dune fields and sand spits. Estuaries in the Northeast are affected by strong sediment drift, which in some cases completely blocks tidal entrances (Lessa et al. 2018), making hard substrata which most macroalgae need for fixation rare or nonexistent. In addition to higher sediment deposition and mobility, there are more turbid waters, which may also explain the lower number of phycological studies, together with the lower sampling effort.

The northernmost lagoon in Brazil with a record of marine macroalgae is Mundaú Lagoon, in Alagoas (Wallner et al. 1986). The author mentions the occurrence of different species of *Enteromorpha* spp., now synonymous with *Ulva* spp., growing mixed on the substrate, making their separation and identification difficult, as they are in an estuary and the species exhibit polymorphism (Wallner et al. 1986). It is unknown if other species of macroalgae occur there, as the focus of the work was on their use as bioindicators of heavy metals in lagoon environments.

There are no studies of macroalgae in the CLs of the Eastern ecoregion or the Amazonian ecoregion despite the presence of some CLs in this region such as Cassange Lagoon (BA) down to the lagoon complex of the Jurubatiba National Park in the northern part of the Rio de Janeiro state. The state of Rio de Janeiro is divided between two ecoregions (Eastern and Southeast) and the Araruama Lagoon is situated at the border. This region is called the "Lakes region" due to the high number of CLs, brackish and freshwater lakes found there. It is the third ecoregion in terms of the number of CLs but concentrates most lagoons with studies of macroalgae, it being nearby five important research institutes at Rio de Janeiro with established expertise in phycological research which are responsible for much of the historical macroalgal research in this lagoon. Furthermore, the Araruama Lagoon presents unique environmental characteristics, particularly its high salinity and the past extraction of shells and salt by the chemical industry for making lye and soda ash, which has attracted considerable research attention over the years.

The Rio Grande marine ecoregion is within the micro-tidal regime and is formed by extensive coastal plains. It has a system of sandy barriers that enclose a very large system, the Patos-Mirim Lagoon Complex, as well as a series of other water bodies isolated or interconnected with the sea through narrow channels. Despite the significant number of CLs, only two have been the subject of studies on marine macroalgae: the Patos Lagoon and the Tramandaí estuary complex, and in both, the studies focused on the lower portion, and no surveys were reported inside the lagoons.

The Patos Lagoon, the largest CL in South America and the largest choked-type lagoon in the world (Lanari et al. 2018a) stands out with the highest number of studies. A total of 17 records were identified, constituting 35.5% of the studies, encompassing taxonomic and ecological studies (5), bioindicators and heavy metals (2), drift macroalgae (4), isotopes (5), and the use of satellite imagery (1). It is worth noting that the only studies involving isotopes in marine macroalgae in CLs have been conducted in the Patos Lagoon. The studies of macroalgae were concentrated in the lower estuary (ELP), but it is known the macroalgal blooms (mainly species of Ulvales and Cladophorales) in those systems may occur within the upper estuary (Gianasi et al. 2011; Coutinho 1982) and even in the limnic portion (Rosa and Garcia 2013), under conditions of

higher temperature, salinity and nutrients found occasionally found in summer. This pattern reflects studies of the Patos Lagoon in general, as more studies have been carried out in the estuary than the whole system or the limnic region (Barbosa and Lanari 2022). This is where the Federal University of Rio Grande (FURG), a pioneer in Oceanographic studies, is located. The larger number of studies in Patos Lagoon is explained in part by the success of the Brazilian Long-Term Ecological Research Program (PELD in Portuguese) (Odebrecht et al. 2017; Lemos et al. 2022), which has been conducting continuous and systematic studies and monitoring of the biota in this estuarine region since 1998 (Lemos et al. 2022). The first ecologically-oriented study of macroalgae was conducted in Patos Lagoon (Coutinho 1982). Following this, other studies were developed in different lagoons such as the Marapendi (Pedrini and Silveira 1985), Mundaú (Wallner et al. 1986), Tijuca (Figueiredo et al. 1989) and Araruama Lagoons (Reis-Santos 1990a, 1990b).

We observed that algal richness and/or abundance generally decreases toward the inner portions of lagoons, away from oceanic exchange (Yoneshigue and Coutinho 1976; Coutinho 1982; Reis-Santos 1990a, 1990b; Reis and Yoneshigue-Valentin 1996; Amaral 2014; Amaral et al. 2018). A similar entrance–interior diversity decline has been described for bays and estuaries (Middelboe et al. 1998), likely related to salinity — a key driver of macroalgal distribution — together with substrate, temperature, light, nutrients, and turbulence (Chapman 1986; Kirst 1990; Lüning 1990; Jahnke and White 2003; Parida and Das 2005; Lee et al. 2007). Opportunistic species dominate inner regions, while diversity is higher near the sea. This pattern is also reported for the Araruama Lagoon (Yoneshigue and Coutinho 1976), despite increasing salinity toward its interior (up to 80) (Reis-Santos 1990b), caused by very low freshwater input and high evaporation, making it the largest permanent hypersaline lagoon ecosystem in the world (Kjerfve 1986). These stable, high-salinity conditions may explain its comparatively high species richness.

The high richness in this lagoon may also reflect the concentration of studies conducted before intense urbanization. Former shell deposits provided algal substrate, but nearly half were removed over 63 years for soda ash production, and substrate loss combined with salinity and temperature variation may explain a one-third reduction in richness over 26 years (CILSJ 2013; Amaral 2014). Urbanization and tourism increased effluent discharge, raising nutrient levels and reducing water transparency (Amaral 2014). Most macroalgae recorded in the eleven lagoons are euryhaline. Although Rhodophyta represented 57% of the taxa, Chlorophyta show greater biomass and regular occurrence, typically dominating inner estuarine and limnic regions while Rhodophyta and Ochrophyta decline. This pattern occurs in several Brazilian lagoons, including the Patos (Coutinho 1982), Rodrigo de Freitas, Tijuca (Reis-Santos 1990b; Amaral 2014; Amaral et al. 2018), and Conceição Lagoons (Böker-Torres et al. 2009). Richness is typically higher near sea connections, declining toward upper lagoon areas with changing salinity.

Although macroalgal richness varied between lagoons we did not observe any correlations with lagoon size, latitude, or salinity. The most abundant taxa in most lagoons are opportunistic genera such as *Ulva*, *Cladophora*, *Chaetomorpha* (Ulvophyceae) and *Bryocladia* (Florideophyceae). These taxa are of high taxonomic complexity which hinder their identification to species level, since

some need confirmation through genetic analyses (Guiry and Guiry 2013). Classification into morphofunctional groups can assist in grouping these taxons and may allow their possible use as bioindicators in a more pragmatic manner.

The systematic review allowed for a comprehensive overview of the knowledge of macroalgae in Brazilian CLs and the identification of knowledge gaps, but some practical difficulties were also observed. For example, we cannot be sure whether the macroalgal groups we describe in the multivariate analyses truly reflect the lagoons' floras, as there might be an underrepresentation of some taxa and/or lagoons depending on the study goal of the source studies. This knowledge gap clearly demonstrates the need for future comparative quantitative studies of the floras of Brazilian lagoons using standardized methods. Another problem was in obtaining very old references and some gray literature, exemplified by studies of the Tramandaí Lagoon. In this respect the digitization of historical collections maintained in libraries is paramount to ensuring their maintenance and accessibility thus making information on baselines for comparison possible. For example, the only record on the phycoflora of Açú Lagoon (RJ) was found in conference proceedings (Yonesshigue-Valentin et al. 2002), acquired from a used bookstore and despite all efforts undertaken here, some of the old literature could not be obtained from any source, and information will certainly be lost over time.

Another practical consideration regards the wide variety of names applied to CLs (Newton et al. 2014), which may have hindered the literature search. According to the same author, even countries with many CLs, such as Portugal and Italy, have different terms (transitional waters, coastal waters, coastal lakes, CLs, wetlands, semi-enclosed bays). The European Water Framework Directive (WFD) uses the term 'transitional waters' which includes some coastal estuarine lagoons, but not all CLs fit the salinity condition (Newton et al. 2018). In Brazilian Portuguese the terms "*lagoa*", "*laguna*" or "*lagoa costeira*" are all used to refer to lagoons.

The importance of CLs in providing ecosystems goods and services has been increasingly recognized (Rodrigues-Filho et al. 2023; Pérez-Ruzafa et al. 2019, 2024; Newton et al. 2014, 2018). The multiple roles played by these systems include the conservation of biodiversity, wildlife refuge, fish nursery, local climate regulation, water purifying, nutrient cycling, food provision, transport, recreation, and cultural and heritage values (Newton et al. 2018). However, due to their position between the land and sea and close to coastal cities, many of these lagoons are under severe threat due to human activities such as urbanization, intensive agriculture, pollution and climate change. Considering the number of CL's in Brazil and their importance to local population, we have demonstrated that the studies about macroalgae in these systems is still incipient, infrequent and concentrated nearby centers of learning.

This urgently needs redressing because marine macroalgae are widely used as ecological indicators worldwide, while coastal systems are increasingly subject to shifting baselines. The first study uing macroalgae as bioindicators in Brazil was conducted in the Patos Lagoon (Seeliger and Cordazzo 1982), and the most recent was by Amaral et al. (2018), who analyzed long-term community changes in three lagoons in the state of Rio de Janeiro. These two studies represent important milestones, the latter being the first to apply an environmental quality index based on macroalgae in Brazilian lagoon environments.

By demonstrating the sensitivity of macroalgal assemblages to anthropogenic pressures and long-term environmental change, Amaral et al. (2018) provided a practical framework for ecological monitoring and management. There is a need (and opportunity) here to integrate macroalgae into, and better exploit, existing national management frameworks such as ReBentos network (Bernardino et al. 2016) and current Marine Spatial Planning (Soares et al. 2025). In this context, our synthesis highlights the knowledge gaps and reinforces the potential of macroalgae as cost-effective indicators to support conservation strategies and environmental assessment in CLs.

We therefore strongly advocate future studies of submerged aquatic vegetation, especially macroalgae, in Brazilian lagoon systems, as the conservation of Brazilian CLs requires basic information and this seems to be largely lacking. Conservation strategies such as the creation of protected areas, the development of sustainable management plans, pollution control, and regular monitoring of water quality and biodiversity all need baselines for comparison and planning. We hope that this study serves as a starting point for future research. A comprehensive analysis of the extent of these ecosystems at the national level is crucial to focus research attention and quantify the ecosystem services they provide (Rodrigues-Filho et al. 2023; Newton et al. 2018). The development of this knowledge is essential to support conservation initiatives and promote the implementation of long-term monitoring protocols by government agencies.

Acknowledgments

We would like to thank two reviewers who comments improved the original manuscript.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Use of AI

No use of AI was reported.

Funding

This work has been supported by CAPES/PROEX and by Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro (JCC, FAPERJ E-26/010.003031/2014 and E26/203.002/2017) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (JCC, CNPq- 305924/2018-4 and 313698/2021-0).

Author contributions

Conceptualization: MC, JCC, HBFA. Formal analysis: MC, HBFA. Funding acquisition: JCC, MC. Investigation: HBFA. Methodology: MC, JCC, HBFA. Resources: HBFA. Visualization: HBFA. Writing - original draft: HBFA. Writing - review and editing: MC, JCC.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

References

Alff CC (2017) Novos registros para a flora de macroalgas marinhas da região de Tramandaí e Imbé, Rio Grande do Sul, Brasil, e elaboração de guia ilustrado das espécies locais. BSc Thesis. Universidade Federal do Rio Grande do Sul, 22 pp.

Amaral HBF, Reis RP, Figueiredo MA de, Pedrini OAG (2018) Decadal shifts in macroalgae assemblages in impacted urban lagoons in Brazil. Ecological Indicators 85: 869–877. https://doi.org/10.1016/j.ecolind.2017.11.055

Amaral HBF (2014) Estrutura das assembleias de macroalgas de três lagunas urbanas após anos. MSc thesis, Instituto de Pesquisa do Jardim Botânico, Escola Nacional de Botânica Tropical, Rio de Janeiro.

Ângulo RJ, Lessa MC, Souza GC (2006) A critical review of Mid- to Late Holocene sea-level fluctuations on the eastern Brazilian coastline. Quaternary Science Reviews 25: 486506. https://doi.org/10.1016/j.quascirev.2005.03.008

Araujo CL (2014) Estudo experimental da acumulação de metais por *Ulva* sp. e *Ruppia maritima*. PhD. Thesis, Universidade Federal Fluminense – UFF. Instituto de Química Pós-Graduação em Geociências – Geoquímica. Tese, 170 pp.

Araujo CL, Suzuki KN, Machado WTV, Bellido AVB, Bellido LF (2017) Studies on Bioaccumulation of Cr-51 by *Ulva* sp. and *Ruppia maritima*. International Scholarly and Scientific Research & Innovation 11: 410–414.

Barbosa FG, Lanari M (2022) Bibliometric analysis of peer-reviewed literature on the Patos Lagoon, southern Brazil. Anais da Academia Brasileira de Ciências 94: e20210861. https://doi.org/10.1590/0001-3765202220210861

Barbosa FA, Scarano FR, Sabará FA, Esteves MG (2004) Brazilian LTER: ecosystem and biodiversity information in support of decision-making. Environmental Monitoring and Assessment 90(1–3): 121–133. https://doi.org/10.1023/b:emas.0000003571.10570.02

Barnes RSK (1980) Coastal Lagoons. The Natural History of a Neglected Habitat. Cambridge University Press, Cambridge, 106 pp.

Bellefontaine SP, Lee CM (2014) Between Black and White: examining Grey Literature in meta-analyses of psychological research. Journal of Child and Family Studies 23(8): 1378–1388. https://doi.org/10.1007/s10826-013-9795-1

Bernardino AF, Netto SA, Pagliosa PR, Barros F, Christofoletti RA, Rosa Filho JS, Colling A, Lana PC (2015) Predicting ecological changes on benthic estuarine assemblages through decadal climate trends along Brazilian Marine Ecoregions. Estuarine, Coastal and Shelf Science 166(Part A): 74–82. https://doi.org/10.1016/j.ecss.2015.05.021

Bernardino AF, Pagliosa PR, Christofoletti RA, Barros F, Netto SA, Muniz P, Lana PC (2016) Benthic estuarine communities in Brazil: moving forward to long term studies to assess climate change impacts. Brazilian Journal of Oceanography 64: 81–96. https://doi.org/10.1590/S1679-875920160849064sp2

Biancamano MIM (1995) Estudo das Macroalgas na Lagoa de Tramandaí, Rio de Grandedo Sul, Brasil. MSc thesis, Universidade Federal do Rio Grande do Sul, 112 pp.

Bird ECF (1994) Physical setting and geomorphology of coastal. In: Kjerfve B (Ed.) Coastal Lagoon Processes. Elsevier, Amsterdam, 9–39. https://doi.org/10.1016/S0422-9894(08)70007-2

Böker-Tôrres M (2005) Composição florística do macrofitobentos da Lagoa da Conceição (Florianópolis, SC). MSc thesis, Universidade Federal de Santa Catarina, Brasil.

Böker-Tôrres M, Bouzon ZL, Horta Jr PA, Ouriques LC (2009) Composição e distribuição do macrofitobentos da Lagoa da Conceição (Florianópolis-SC). Insula Revista de Botânica 38: 70–115.

Borowitzka MA (1972) Intertidal algal species diversity and the effect of pollution. Australian Journal of Marine and Freshwater Research 23: 3–84. https://doi.org/10.1071/MF9720073

Brauko KM, Cabral A, Costa NV, Hayden J, Dias CEP, Leite ES, Westphal RD, Mueller CM, Hall-Spencer JM, Rodrigues RR, Rörig LR, Pagliosa PR, Fonseca AL, Alarcon OE, Horta PA (2020) Marine heatwaves, sewage and eutrophication combine to trigger deoxygenation and biodiversity loss: A SW Atlantic case study. Frontiers in Marine Science 7: 590258. |https://doi.org/10.3389/fmars.2020.590258

Breitburg D, Levin LA, Oschlies A, Grégoire M, Chavez FP, Conley DJ, Garçon V, Gilbert D, Gutiérrez D, Isensee K, Jacinto GS, Limburg KE, Montes I, Naqvi SWA, Pitcher GC, Rabalais NN, Roman MR, Rose KA, Seibel BA, Telszewski M, Yasuhara and Zhang MJ (2018) Declining oxygen in the global ocean and coastal waters. Science. v.359(6371): eaam7240. https://doi.org/10.1126/science.aam7240

Cantanhêde SM, Sodré-Campos VC, Pereira DP, Medeiros AM, Fortes-Carvalho-Neta RN, Tchaicka L, Silva-Santos DM (2018) Parasitism in gills of *Centropomus undecimalis* (Pisces, Centropomidae) from a protected area in São Luís, Maranhão, Brazil. Latin American Journal of Aquatic Research 46(2). https://doi.org/10.3856/vol46-issue2-fulltext-13

Chapman ARO (1986) Population and community ecology of seaweeds. Advances in Marine Biology. London Academic Press 23: 1–161. https://doi.org/10.1016/S0065-2881(08)60108-X

Church JA, Clark PU, Cazenave A, Gregory JM, Jevrejeva S, Levermann A, Merrifield MA, Milne GA, Nerem RS, Nunn PD (2013) Sea Level Change. In: Stocker TF, Qin D, Plattner G-K, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (Eds) The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, . Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1137–1216. https://doi.org/10.1126/science.342.6165.1445-a

CILSJ (2013) Consórcio Intermunicipal Lagos São João. http://www.lagossaojoao.org.br/la-usos.htm [accessed on 22 March 2023]

Claudino MC (2012) Variações temporais e espaciais na composição isotópica de produtores primários e consumidores no estuário da Lagoa dos Patos, RS. MSc thesis. Pós-Graduação em Oceanografia Biológica, Universidade Federal do Rio Grande.

Connell SD, Russell BD, Turner DJ, Shepherd SA, Kildea T, Miller D, Airoldi L, Cheshire A (2008) Recovering a lost baseline: missing kelp forests from a metropolitan coast. Marine Ecology Progress Series 60: 63–72. https://doi.org/10.3354/meps07526

Copertino MS, Seeliger U (2010) Hábitats de *Ruppia marítima* e algal. In: Seeliger, U. and Odebrecht, C. O Estuário da Lagoa dos Patos: um século de transformações. EdFURG, Rio Grande.

Copertino MS, Creed JC, Lanari MO, Magalhães K, Barros K, Lana PC, Sordo L, Horta PA (2016) Seagrass and Submerged Aquatic Vegetation (VAS) Habitats off the Coast of Brazil: state of knowledge, conservation and main sthreats. Brazilian Journal of Oceanography 64: 53–80. https://doi.org/10.1590/S1679-875920161036064sp2

Coutinho, Seeliger RU (1984) The horizontal distribuition of the bentich algal flora in the Patos Lagoon estuary, Brazil, in relatioon to salinity, substratum and wave exposure. Journal of Experimental Marine Biology and Ecology 80: 241–257. https://doi.org/10.1016/0022-0981(84)90153-9

Coutinho R, Seeliger U (1986) Seasonal occurrence and growth of benthic algae in the Patos Lagoon estuary, Brazil. Estuarine, Coastal and Shelf Science 23: 889–900. https://doi.org/10.1016/0272-7714(86)90079-X

Coutinho R (1982) Taxonomia, distribuição, crescimento sazonal, reprodução e biomassa das algas bentônicas no Estuário da Lagoa dos Patos. MSc thesis, Programa de Pós-Graduação em Oceanografia Biológica, Universidade Federal do Rio Grande (RS), Brasil.

Creed JC, Casares FA (2005) Bancos de macrófitas marinhas: são oásis de diversidade nos desertos de substratos não consolidados. In: Anais. X Reunião da Sociedade Brasileira de Ficologia – Formação de ficólogos: um compromisso com a sustentabilidade dos recursos aquáticas. Museu Nacional, Rio de Janeiro, 221–237.

Creed JC, Aranda LS, de Sousa JG, Brito do Bem CB, Dutra BSVM, Lanari M, de Sousa VE, Magalhães KM, Magris RA, Vivanco-Bercovich M et al. (2023) A Synthesis of Provision and Impact in Seagrass Ecosystem Services in the Brazilian Southwest Atlantic. Sustainability 15: 14722. https://doi.org/10.3390/su152014722

Cromwell JE (1971) Barrier coast distribution: a world-wide survey. Abstract vol. Second National Coastal and Shallow Water Research Conference, 50 pp.

Cruz O, Coutinho PN, Duarte GM, Gomes AMB (1985) Brazil. In: Bird ECF, Schwartz ML (Eds) The world's coastline. New York : Van Nostrand Reinhold Co., 85–91.

Cunha LC (1996) Dinâmica de nutrientes e biomassa algal no sistema lagunar de Piratininga, Niterói, RJ: efeitos da instalação de uma comporta. MSc thesis. Programa de Pós-Graduação em Geociências da Universidade Federal Fluminense, Niteroi.

Paula De JC, Pedrini AG (1998) *Audouinella sancti-thomae*: referência nova para a costa Atlântica Sul Americana. IV Simpósio Latinoamericano de Ficologia. Sociedade Ficológica da América Latina e Caribe, São Paulo 2: 379–387.

Witt De R (2011) Biodiversity of Coastal Lagoon Ecosystems and Their Vulnerability to Global Change. Ecosystems Biodiversity. https://doi.org/10.5772/24995

Dias CEP (2024) Avaliação dos efeitos de estressores globais e locais sobre bancos da grama marinha *H. wrightii*: uma abordagem mensurativa e experimental. MSc thesis. Universidade Federal de Santa Catarina, 60 pp.

Esteves BS, Taouil A, Suzuki MS (2005) Nutrient composition of macroalgae and macrophytes of the Açu lagoon, Rio de Janeiro State, Brazil. Acta Limnologica Brasiliensia 17(3): 233–244.

Esteves F, Caliman A, Santangelo J, Guariento R, Farjalla V, Bozelli R (2008) Neotropical coastal lagoons: an appraisal of their biodiversity, functioning, threats and conservation management. Brazilian Journal of Biology 68(4): 967–981. https://doi.org/10.1590/S1519-69842008000500006

Esteves FA (1998) Fundamentos de Limnologia. Interciência/FINEP, Rio de Janeiro.

FAO (2018) Food and Agriculture organization of the United Nations. The state of world fisheries and aquaculture. https://doi.org/10.18356/0170ea0f-en [accessed on 10 November 2023]

Ferreira ABG (2020) Macroalgas marinhas: conhecimentos tradicionais e serviços ecossistêmicos. MSc thesis. Universidade Federal do Rio Grande do Norte Natal, Rio Grande do Norte.

Figueiredo MAO, Mourão CB, Yoneshigue-Valentin Y (1989) Polimorfirmo de *Grateloupia* C. Agardh (Halymeniaceae - Rhodophyta) no estuário do complexo lagunar de Jacarepaguá. IV Reunião da Sociedade Brasileira de Ficologia 19: 115–132.

Garcia AM, Claudino MC, Mont'Alverne RM, Pereyra Copertino PER, Vieira M (2016) Temporal variability in assimilation of basal food sources by an omnivorous fish at Patos Lagoon Estuary revealed by stable isotopes (2010–2014). Marine Biology Research 98–107. https://doi.org/10.1080/17451000.2016.1206939

Gianasi BL, Oliveira AO, Araujo MLV, Copertino MS (2011) Utilização de LANDSAT-TM no estudo de uma floração de macroalgas de deriva no Estuário da Lagoa dos Patos (RS, Brasil). Anais. XV Simpósio Brasileiro de Sensoriamento Remoto – SBSR. Curitiba, Paraná.

Guiry MD, Guiry GM (2013) Algae base. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebas.org [accessed on 20 March 2023]

Hasselström L, Visch W, Gröndahl F, Göran MN, Pavia H (2018) The impact of seaweed cultivation on ecosystem services: a case study from the west coast of Sweden. Marine Pollution Bulletin 133: 53–64. https://doi.org/10.1016/j.marpolbul.2018.05.005

Hayes MO (1975) Morphology of sand accumulation in estuaries: na introdutction to the symposium. In: Cronin LE (Ed.) Estuarine Research, Academic Press, New York 11: 3–22. https://doi.org/10.1016/b978-0-12-197502-9.50006-x

Jahnke LS, White AL (2003) Long-term hyposaline and hypersaline stresses produce distinct antioxidant responses in the marine alga *Dunaliella tertiolecta*. Journal of Plant Physiology 160(10): 1193–1202. https://doi.org/10.1078/0176-1617-01068

Kennish MJ (2015) Coastal Lagoons. In: Kennish MJ (Eds) Encyclopedia of Estuaries. Encyclopedia of Earth Sciences Series. Springer, Dordrecht. https://doi.org/10.1007/978-94-017-8801-4_47

Kirst G (1990) Salinity Tolerance of Eukaryotic Marine Algae. Environmental Science, Biology. Annual Review of Plant Physiology and Plant Molecular Biology 41: 21–53. https://doi.org/10.1146/ANNUREV.PP.41.060190.000321

Kjerfve B (1986) Comparative oceanography of coastal lagoons. In: Wolf DA (Ed.) Estuarine variability. Academy Press, New York, 63–81. https://doi.org/10.1016/b978-0-12-761890-6.50009-5

Kjerfve B (1994) Coastal Lagoons. In: Kjerfve B (Ed.) Coastal Lagoon Processes, Elsevier Oceanographic Series, Amsterdam, 1–8. https://doi.org/10.1016/S0422-9894(08)70006-0

Knoppers B, Souza W, Ekau W, Figueiredo Jr AG, Soares-Gomes A (2009) A interface Terra-Mar do Brasil. In: Biologia Marinha. Interciência, Rio de Janeiro, 529–554.

Lanari M, Copertino M (2016) Drift macroalgae in the Patos Lagoon Estuary (southern Brazil): effects of climate, hydrology and wind action on the onset and magnitude of blooms. Marine Biology Research 13: 36–47. https://doi.org/10.1080/17451000.2016.1225957

Lanari M (2016) Macroalgas de deriva no estuário da Lagoa dos Patos (RS, Brasil): fatores hidrológicos, estoque de nutrientes e efeitos na comunidade bentônica. PhD thesis, Oceanografia Biológica. Universidade Federal do Rio Grande, FURG, Brasil.

Lanari M, Claudino MC, Garcia AM, Copertino MS (2018b) Changes in the elemental (C, N) and isotopic (δ 13 C, δ 15 N) composition of estuarine plants during diagenesis and implications for ecological studies. Journal of experimental marine biology and ecology, 500: 46–54. https://doi.org/10.1016/j.jembe.2017.12.013

Lanari M, Copertino MS, Colling LA, Bom FC (2018a) The impact of short-term depositions of macroalgal blooms on widgeon-grass meadows in a river-dominated estuary. Harmful Algae 78: 36–46. https://doi.org/10.1016/j.hal.2018.07.006

Lanari M, Kennedy H, Copertino MS, Wallner-Kersanach M, Claudino MC (2017) Dynamics of estuarine drift macroalgae: growth cycles and contributions to sediments in shallow areas. Marine Ecology Progress Series 570: 41–55. https://doi.org/10.3354/meps12116

Lanari M, Possamai B, Copertino MS, Garcia AM (2021a) Seasonal and El Niño Southern Oscillation-driven variations in isotopic and elemental patterns among estuarine primary producers: implications for ecological studies. Hydrobiologia 848: 593–611. https://doi.org/10.1007/s10750-020-04462-0

Lanari M, Possamai B, Copertino MS, Garcia AM (2021b) Dataset on the isotopic (13C, 15N) and elemental (C, N) composition of estuarine primary producers in the subtropical Southwestern Atlantic coast. Latin American Data in Science 1: 8–15. https://doi.org/10.53805/lads.v1i1.10

Lavrado HL (1998) Ecofisiologia, produção primária e modelagem de macroalgas na Lagoa de Araruama, RJ. PhD thesis, Universidade Federal do Rio de Janeiro, Rio de Janeiro.

Lee W, Tillo D, Bray N, Morse RH, Davis. RW, Hughes TR, Nislow C (2007) A high-resolution atlas of nucleosome occupancy in yeast. Nature Genetics 39: 1235–1244. https://doi.org/10.1038/ng2117

Lemos VM, Lanari M, Copertino M, Secchi ER, Abreu PCOV, Muelbert JH, Garcia AM, Dumont FC, Muxagata E, Vieira JP, Colling A, Odebrecht C (2022) Patos Lagoon estuary and adjacent marine coastal biodiversity long-term data. Earth System Science Data 14: 1015–1041. https://doi.org/10.5194/essd-14-1015-2022

Lessa G, Santos FM, Souza Filho PW, Gomes LCC (2018) Brazilian Estuaries: a Geomorphologic and Oceanographic Perspective. In: Lana PC, Bernardino AF (Eds) Brazilian Estuaries: a benthic perspective. Springer, Cham, 1–37. https://doi.org/10.1007/978-3-319-77779-5_1

Ligorini V, Crayol E, Huneau F, Garel E, Malet N, Garrido M, Simon L, Cecchi P, Pasqualini V (2023) Small Mediterranean coastal lagoons under threat: Hydro-ecological disturbances and local anthropogenic pressures (size matters). Estuaries and Coasts 46: 2220–2243. https://doi.org/10.1007/s12237-023-01182-1

Loureiro RR, Reis RP (2008) Efeito do gradiente de salinidade na taxa fotossintética de *Polysiphonia subtilissima* Mont., *Cladophora vagabunda* (Linnaeus) van den Hoek e *Ulva flexuosa* (Wulfen) J. Agardh subsp. *flexuosa* da Lagoa Rodrigo de Freitas, Rio de Janeiro, Brasil. Rodriguésia 59: 291–296. https://doi.org/10.1590/2175-7860200859202

Loureiro RR (2007) Caracterização das assembleias de macroalgas da Lagoa Rodrigo de Freitas, Rio de Janeiro, Brasil. MSc thesis. Instituto de Pesquisas Jardim Botânico, Rio de Janeiro.

Lourenço SO, Barbarino E, Nascimento A, Paranhos R (2005) Seasonal variations in tissue nitrogen and phosphorus of eight macroalgae from a tropical hypersaline coastal environment. CryptogamieAlgologie 26(4): 355–371.

Lüning K (1990) Seaweeds: their environment, biogeography, and ecophysiology. Wiley & Sons, New York. https://doi.org/10.1002/aqc.3270010208

Marinho-Soriano E; Carneiro MAA (2021) Macroalgas marinhas: biologia, ecologia e importância econômica. In: Viana DL, Oliveira JEL, Hazin FHV, Souza MAC (Eds) Cências do mar: dos oceanos do mundo ao nordeste do Brasil. Olinda, PE: Via Desing Publicações.

Middelboe AL, Sand-Jensen K, Krause-Jensen D (1998) Patterns of macroalgal species diversity Danish estuaries. Journal of Phycology 34: 457–466. https://doi.org/10.1046/j.1529-8817.1998.340457.x

Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, Shekelle P, Stewart LA (2015) Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Systematic Reviews 4. https://doi.org/10.1186/2046-4053-4-1

Newton A, Brito AC, Icely JD, Derolez V, Clara I, Angus S, Schernewski G, Inácio M, Lillebø AI, Sousa AI, Béjaoui B, Solidoro C, Tosic M, Cañedo-Argüelles M, Yamamuro M, Reizopoulou S, Tseng HC, Canu D, Roselli L, Khokhlov V (2018) Assessing, quantifying and valuing the ecosystem services of coastal lagoons. Journal for Nature Conservation, Elsevier 44: 50–65. https://doi.org/10.1016/j.jnc.2018.02.009

Newton A, Icely J, Cristina S, Brito A, Cardoso AC, Colijn F, Rirova SD, Gertz F, Hansen JW, Holmer M, Ivanova K, Leppäkoski E, Canu DM, Mocenni C, Mudge S, Murray N, Pejrup M, Razinkovas A, Reizopoulou S, Zaldívar JM (2014) An overview of ecological status, vulnerability and future perspectives of European large shallow, semi-enclosed coastal systems, lagoons and transitional waters. Estuarine, Coastal and Shelf Science 140: 95–122. https://doi.org/10.1016/j.ecss.2013.05.023

Odebrecht C, Secchi ER, Abreu PC, Muelbert JH, Uiblein F (2017) Biota of the Patos Lagoon estuary and adjacent marine coast: long-term changes induced by natural and human-related factors Marine Biology Research. https://doi.org/10.1080/17451000.2016.1258714

Oliveira LPH (1948) Estudo hidrobiológico das Lagoas de Piratininga e Itaipú. Memórias do Instituto Oswaldo Cruz 46(4): 115–125. https://doi.org/10.1590/s0074-02761948000400003

Oppenheimer M, Glavovic B, Hinkel J, Van de Wal R, Magnan AK, Abd-Elgawad A,Cai R, Cifuentes-Jara M, DeConto RM, Ghosh T, Hay J, Isla F, Marzeion B, Meyssignac B, Sebesvari ZZ (2019) Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities. Sea Level Rise and Implications for Low Lying Islands, Coasts and Communities. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. Cambridge University Press, Cambridge, UK and New York, NY, USA. https://doi.org/10.1017/9781009157964.006

Orfanidis S, Panayotidis P, Ugland KI (2011) Ecological Evaluation Index continuous formula (EEI-c) application: a step forward for functional groups, the formula and reference condition values. Mediterranean Marine Science 12(1): 199–231. https://doi.org/10.12681/mms.60

Ortega JLG (2000) Algas. In: Espino GL, Pulido SH, Pérez JLC (Eds) Organismos indicadores de la calidad del água y de la contaminación (Bioindicadores). Playa y Valdés, México, 109–193.

Page MJ, Moher D, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD et al. (2021) PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. British Medical Journal 372(160). https://doi.org/10.1136/bmj.n160

Pagliosa PR, Cantor M, Scherner F, Otegui MBP, Lemes-Silva AL, Martins CDL, Alves GF, Fonseca A, Horta Jr PA (2012) Influence of piers on functional groups of benthic primary producers and consumers in the channel of a subtropical coastal lagoon. Brazilian Journal of Oceanography 60(1): 65–73. https://doi.org/10.1590/S1679-87592012000100007

Parida AK, Das AB (2005) Salt tolerance and salinity effects on plants: a review. Ecotoxicology and Environmental Safety 60(3): 324–349. https://doi.org/10.1016/j.ecoenv.2004.06.010

Pedrini AG, De-Paula J (1997) Algas Bentônicas da Lagoa de Piratininga, Niterói, RJ, Brasil. Albertoa 4(18): 233–244.

Pedrini AG, Silveira ICA (1985) Composição taxonômica e estimativa da biomassa das macroalgas epífitas em *Ruppia marítima* L. na Lagoa de Marapendi. Atas da Sociedade Botânica do Brasil 3(6): 45–60.

Pedrini AG, De-Paula JC, Barreto MBB (1998) Algas bentônicas da Lagoa de Itaipu, Niterói, RJ, Brasil: composição taxonômica e variação espaço-temporal. IV Simpósio Latinoamericano de Ficologia, Sociedade Ficológica da América Latina e Caribe, São Paulo 2: 217–231.

Pedrini AG, Monteiro MHDA, De-Paula JC (2002) Algas Bentônicas da Lagoa de Piratininga, Niterói, RJ, Brasil: composição taxonômica e variação espaço temporal 2002. Revista de Estudos Ambientais 3: 98–109.

Pérez-Ruzafa A, Molina-Cuberos GJ, García-Oliva M, Umgiesser Marcos GC (2024) Why coastal lagoons are so productive? Physical bases of fishing productivity in coastal lagoons. The Science of the total environment 922: 171264. https://doi.org/10.1016/j.scitotenv.2024.171264

Pérez-Ruzafa A, Pérez-Ruzafa I, Newton A, Marcos C (2019) Chapter 15 - coastal lagoons: environmental variability, ecosystem complexity, and goods and services uniformity. In: Wolanski E, Day JW, Elliott M, Ramachandran R (Eds) Coasts and Estuaries. Elsevier, 253–276. https://doi.org/10.1016/B978-0-12-814003-1.00015-0

Prado JF (1989) Algas Marinhas Macroscópicas (Chlorophyta, Phaeophyta, Rhodophyta) da Região de Tramandaí e Imbé, RS, Brasil. MSc thesis, Universidade Federal do Rio Grande do Sul. https://doi.org/10.5902/2179460x26308

Prado JF (1991) Algas marinhas macroscópicas (Chlorophyta, Phaeophyta, Rhodophyta) da região de Tramandai e Imbé- RS, Brasil. 1991. Ciência e Natura, Santa Maria 13: 133–138. https://doi.org/10.5902/2179460x26308

Raven PH, Eichhorn SE, Evert RF (2014) Biologia Vegetal -8ª. Edn. Rio de Janeiro. Guanabara Koogan.

Reis RP, Yoneshigue-Valentin Y (1996) Distribuição das macroalgas na Lagoa de Araruama, Estado do Rio de Janeiro, Brasil. Revista Brasileira de Botânica 19(1): 77–85.

Reis-Santos RP (1990a) Variações morfológicas das Chlorophyta da Lagoa de Araruama, Rio de Janeiro. Rodriguésia 42/44: 25–37. https://doi.org/10.1590/2175-786019901992424468700 3

Reis-Santos RP (1990b) Flora algal da Lagoa de Araruama, Rio de Janeiro. MSc thesis, Museu Nacional, Universidade Federal do Rio de Janeiro, Rio de Janeiro.

Rodrigues-Filho JL, Macêdo RL, Sarmento H, Pimenta VRA, Alonso C, Teixeira CR, Pagliosa PR, Netto SA, Santos NCL, Daura-Jorge FG, Rocha O, Horta P, Branco JO, Sartor R, Muller J, Cionek VM (2023) From ecological functions to ecosystem services: linking coastal lagoons biodiversity with human well-being. Hydrobiologia 850: 2611–2653. https://doi.org/10.1007/s10750-023-05171-0

Rosa VC, Garcia M (2013) Ocorrência de *Ulva* spp., *Polysiphonia* sp., e *Microcystis aeruginosa* nas praias do Saco do Laranjal, Pelotas, 2013. Revista Thema 10(1). https://doi.org/10.15536/thema.10.2013.122-137.127

Sá MM, Guimarães ICA (1984) Estudo taxonômico preliminar da flora ficológica bentônica da Lagoa de Itaipu, Niterói, Rio de Janeiro, Brasil. Espaço 9: 79–128.

Santos DMS, Melo MRS, Mendes DCS, Rocha IKBS, Silva JPL, Cantanhêde SM, Meletti PC (2014) Histological Changes in Gills of Two Fish Species as Indicators of Water Quality in Jansen Lagoon (São Luís, Maranhão State, Brazil) 2014. International Journal of Environmental Research and Public Health 11(12): 12927–12937. https://doi.org/10.3390/ijerph111212927

Scherner F, Ventura R, Barufi Horta JBPA (2013) Salinity critical threshold values for photosynthesis of two cosmopolitan seaweed species: providing baselines for potential shifts on seaweeds assemblages. Marine Environmental Research 91: 14–25. https://doi.org/10.1016/j.marenvres.2012.05.007

Schramm W (1999) Factors influencing seaweed responses to eutrophication: some results from EU-project EUMAC. Journal of Applied Phycology 11: 69–78. https://doi.org/10.1023/A:1008076026792

Seeliger U, Cordazzo C (1982) Field and experimental evaluation of *Enteromorpha* sp. As a quali-quantitative monitoring organism for copper and mercury in estuaries. Enrironmental Pollution (Series A), 29: 197–206. https://doi.org/10.1016/0143-1471(82)90164-7

Siqueira L, Barbieri R, Rojas Costa M, Neto J (2011) Bioensaio e estudo da acomodação de *Ruppia maritima* L. da Laguna da Jansen, São Luis-MA (Brasil). Acta Tecnológica 6(1): 62–2. https://doi.org/10.35818/acta.v6i1.43

Soares MA, Silva C, Lyra RS, Assad LPF, Pimentel LCG, Landau L (2025) Contributions to marine spatial planning in the Brazilian coastal region. Aracê 7: 35891–35906. https://doi.org/10.56238/arev7n7-044

Souza CRG, Suguio K, Oliveira AMS, Oliveira PE (2005) Quaternário do Brasil. Holos, Ribeirão Preto, São Paulo. https://doi.org/10.35699/2237-549X.13210

Spalding MD, Fox HE, Allen GR, Davidson N, Ferdaña ZA, Finlayson M, Halpern BS, Jorge MA, Lombana A, Lourie SA, Martin KD, McManus E, Molnar J, Recchia CA, Robertson J (2007) Marine ecoregions of the world: a bioregionalization of coastal and shelf areas. Journal of Biosciences 57(7): 573–583. https://doi.org/10.1641/B570707

Wallner M, Seeliger U, Teixeira VL, Joventino FP, Silva SC (1986) Variações regionais na concentração de metais pesados na macroalga *Enteromorpha* sp. dos estuários do Rio Ceará (Ceará), Lagoa de Mundaú (Alagoas) e Lagoa da Tijuca (Rio de Janeiro). Arquivos de Ciências. Mar, 41–50.

Yoneshigue YB, Coutinho R (1976) Flora Ficológica da Lagoa Hipersalina de Araruama (Estado do Rio de Janeiro). Undergraduate research report CNPq, 30 pp.

Yonesshigue-Valentin Y, Taouil A, Oliveira VP (2002) Vegetação Submersa da Lagoa do Açu (Estado do Rio de Janeiro - Brazil). Abstract, IX Reunião Brasileira de Ficologia. Santa Cruz - Aracruz - ES.

Supplementary material 1

List of coastal lagoons in Brazil and list of occurrence of macroalgal taxons in each lagoon

Authors: Hanna Brum François Amaral, Margareth da Silva Copertino, Joel Christopher Creed

Data type: xlsx

Explanation note: Excel file with four sheets, one with a list of coastal lagoons identified in the present study, one with a list and categorization of 48 studies, one with a list of taxons from the 48 studies and one with the results of Multi-Dimensional Scaling (MDS).

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Link: https://doi.org/10.3897/emt.3.186569.suppl1